MODELLING OF PAD SUPPORT FOR FOOT OSTEOARTHRITIS

MOHD ELEY BIN ROSLI

A thesis submitted in

fulfilment of the requirement for the award of the

Degree of Master of Mechanical Engineering

FACULTY OF MECHANICAL AND MANUFACTURING ENGINEERING

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

JANUARY 2015

ABSTRACT

Osteoarthritis (OA) is a disease that affects joints or ankles of human body that will cause the patients of this disease feels pain, swelling and stiffness in the joint. Human who was affected by the foot osteoarthritis (OA) disease always have problem in doing daily activities due to the pain at their foot. OA patients will always feel pain and stiffness in the inflammation joint. They also feel swelling in or near that joint. These symptoms will always make them difficult in walking and bending their affected joints or ankles when doing daily activities. In relieve the pain that having by the patient, a research of developing the pad support had been done. Development of pad support for osteoarthritis patient which is focused on big toe osteoarthritis become a subject of study and ABAQUS 6.13 software is selected as preferred software to design the geometry of pad support and analysed it using finite element analysis. The CAD model of the pad support then imposed to pressure load to study the effect of this pressure load upon proposed geometries and materials. Three types of geometry models and three types of materials used have been studied for this project. Then the results of the analysis had been discussed by observing to three parameters which is stress, pressure and reaction force. Lastly, the development of big toe osteoarthritis pad support had been studied.

ABSTRAK

Osteoarthritis (OA) merupakan sejenis penyakit yang menjangkiti sendi manusia yang boleh menyebabkan pesakit berasa sakit dan kebas pada bahagian sendi. Manusia yang dijangkiti penyakit OA pada bahagian kaki selalunya akan menghadapi kesukaran dalam melakukan tugasan seharian disebabkan oleh kesakitan yang dialaminya pada bahagian sendi kaki. Rasa sakit dan kebas ini akan sentiasa memberi kesukaran kepada pesakit semasa berjalan dan melakukan kerja yang melibatkan pembengkokkan sendi. Dalam mengurangkan kesakitan yang dihadapi oleh pesakit OA, satu kajian tentang pembangunan pad sokongan telah dilakukan. Pembangunan pad sokongan untuk pesakit OA yang mana memfokuskan kepada bahagian ibu jari kaki telah menjadi satu tajuk untuk dikaji dan perisian ABAQUS 6.13 dipilih untuk merekabentuk sturktur geometri pad sokongan dan menganalisisnya dengan kaedah analisis unsur terhingga. Pad sokongan kemudiannya akan didedahkan kepada beban tekanan bagi mengkaji tindakbalasnya terhadap struktur geometri dan bahan yang dicadangkan. 3 jenis model geometri dan 3 jenis penggunaan bahan telah dikaji dalam projek ini. Kemudian, keputusan yang diperolehi daripada analisis telah dibincangkan berdasarkan kepada pemantauan terhadap 3 parameter iaitu tegasan, tekanan dan daya tindak balas. Akhirnya, pembangunan pad sokongan bagi pesakit OA pada bahagian ibu jari kaki telah dikaji.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

OA	Osteoarthritis
CAD	Computer Aided Design
CAE	Computer Aided Engineering
MPa	Mega Pascals
N	Newton
NR	Natural Rubber
PC	Polypropylene Copolymer
OCPF	Open Cell Polyurethane Foam

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Arthritis is a disease that affects joints or ankles of human body. This disease commonly involves ankles that support body weight like hip, spine, knee and foot. There are more than hundred types of arthritis in the world and the most common form of arthritis that affected million on Americans is osteoarthritis (OA). Usually an OA appear at the foot which are in the big toe, middle foot and ankle. The characteristic of OA can be determined by damage of connective tissue at the end of the bones in the joints known as cartilage. This cartilage is use to protect and cushions the bones during movement in daily activities. With repeated stress of the joint may cause the cartilage tissue wear and tear that lead to OA disease (Consumer Education Committee, 2010).

OA also known as degenerative arthritis will cause the patient of this disease feel pain, swelling and stiffness in the joint. They also hard to do any movement like walking and bending the joints. This OA disease can be treat either non-surgical method or surgical method. The non-surgical method become the main choice by the patients to relieve the pain, reduce disability and provide support to help their live as active a life as possible (NHS Choices, 2014). If the non-surgical treatments fail to reduce the pain, surgical method may be recommended. This is because the non-surgical method is cost effective than surgical method.

1.2 Problem Statement

Human who was affected by the foot OA disease always have problem in doing daily activities due to the pain at their foot. OA patients will always feel pain and stiffness in the inflammation joint. They also feel swelling in or near that joint. These symptoms will always make them difficult in walking and bending their affected joints or ankles when doing daily activities.

The treatments should be done to OA patients to help them relieve their symptom either by non-surgical treatment nor surgical treatment. The cost of the surgical treatment is high rather than non-surgical treatment. Because of that patient who is early affected by OA will ignore the symptom and do daily activities as always. This will make the disease become worse and it can be prevented from happen by wearing some orthotic device.

1.3 Project Objectives

Based on the problem statement, an orthotic device can provide support to improve foot's mechanics or cushioning to help reduce the patient symptoms. There are three objectives that must be achieved for this research which are:

i. To model pad supports for foot OA patient which is at the toe part.
ii. To study the effect of selected homogeneous and heterogeneous material used on pad supports.
iii. To determine the effect of geometrical structure of pad supports.

1.4 Project Scope

The foot OA usually occurs at toe, mid-foot and ankles which is always happened to elderly. In this research of foot OA, we will focused on toe part disease which are big toe. These kinds of foot OA disease can be prevented from be worsen by using

the pad support during walking or do any activities that use the foot. In achieve the goal of this research, the following method must be done:

i. Study the characteristics of big toe OA disease.
ii. Literature review on design, geometrical structure and material use of existing pad supports for foot OA patient.
iii. Design, geometrical structure and material use of pad supports for foot OA patient by using ABAQUS.
iv. Test the pad supports for foot OA patient by using Finite Element Analysis (FEA) method.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will provide a comprehensive review related to the topic contain in this study. It will explain on the OA disease that affected human ankle and joint. In conclusion, this chapter will briefly explained further on the foot OA, its characteristic and symptom and the current treatment use to cure the diseases.

2.2 Osteoarthritis

Arthritis is a form of joint disorder that involves inflammation of one or more joint. There more than 100 forms of arthritis disease but the most common form of arthritis is osteoarthritis that affects millions of human in the world (Consumer Education Committee, 2006). According to Berenbaum (2012) OA has long been considered a “wear and tear” disease leading to loss of cartilage. OA used to be considered the sole consequence of any process leading to increased pressure on one particular joint (e.g., overload on weight-bearing joints, anatomical joint incongruency) or fragility of cartilage matrix (genetic alterations of matrix components).

OA also known as degenerative arthritis and degenerative joint disease is a group of mechanical abnormalities that involves degradation of the joints. Consumer

Education Committee (2006) state that the OA is a condition characterized by breakdown and eventual loss of cartilage which is connective tissue at the end of the bone of the joints in one or more joint as shown in Figure 2.1. OA appears at various joints throughout the body including hands, feet, spine, hips and knees. In the foot, the disease most frequently occurs in the big toe or hallux.

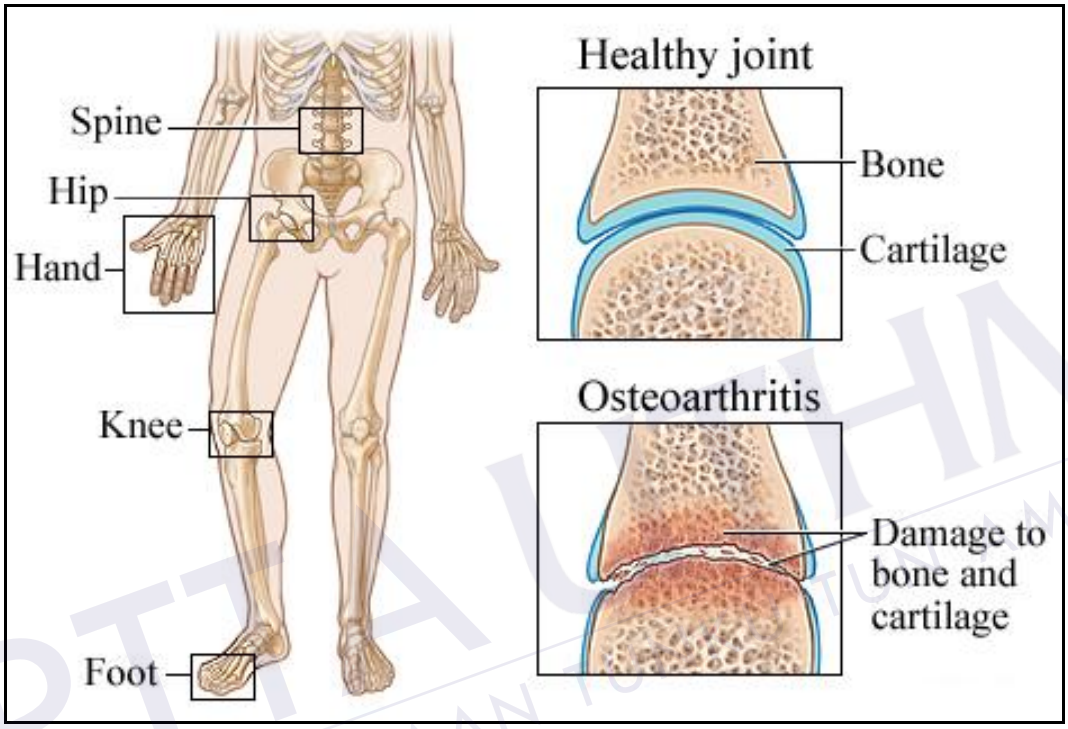

Figure 2.1: Comparative between healthy joint and osteoarthritis joint. (WebMD, 2013)

The cartilage between the bones at the joint is used to protect and cushions the connecting bone during the movements of the joints or ankles. When this connective tissue tears or wears, the bone at the joints will be touching each other without any protection. This will develop the symptoms that can restrict the ability of OA patients to easily perform daily activities. According to Consumer Education Committee (2006), the signs and symptoms of human who affected by this disease are:

- Pain at the joint - a sharp ache or a burning sensation in the associated muscles and tendons.
- Stiffness in the joint - feel numb around the ankle when long times stand.

- Swelling in and around the joint when doing any movement of the joints or ankles.
- Difficulty in walking and bending the joint - cause by friction between two bones without lubricant as shown in Figure 2.2.

Figure 2.2: Friction between two bones at the ankle. (Houston Methodist Orthopedics & Sports Medicine, 2014)

According to the Arthritis Care (2012), the OA occurs when the cartilage which is allows the bones moves smoothly in the joint become damaged. It means that the joint is no longer protected and the bone will rub together when have any movement. This will cause pain and inflammation of the joint. The cartilages wear down because of repeated stress due to the daily activities. It also can be wear when the joint move over time without any rest. In some case, this connective tissue will tear up due to the impact stress while doing some sport activities like football, soccer, hiking and others.

2.3 Foot Osteoarthritis

This research will be focused on one types of foot OA which is happened in foot. There are more than 30 joints that can be affected by the OA diseases at the foot. Some types of foot OA that always affect human foot are big toe, hammer toes, arch

pain, bunions, corns and calluses. All these types of foot OA have their own characteristics. The symptoms of these is same which are pain, stiffness and swelling around the joints. But their features are different between each others. The big toe OA will be focused on this research.

Figure 2.3: The arch pain in the middle of foot. (FootWise Podiatry, 2005)

The arch pain is one of foot OA that affects the joint in the middle foot. Patient will feel pain and discomfort at the arch area as shown in Figure 2.3 which is helps distribute the weight of the body over the foot. The discomfort can develop into a burning sensation if the muscles and tendons are overworked. Different features show in hammer toes osteoarthritis where the toes is permanently bend, the base pointing up and the end of toe is pointing down as shown in Figure 2.4. This type OA affected cause by wearing tight shoes that can squash the toes or a knock-on effect by a bunion OA or tendon problem inside the foot (Arthritis Care, 2012).

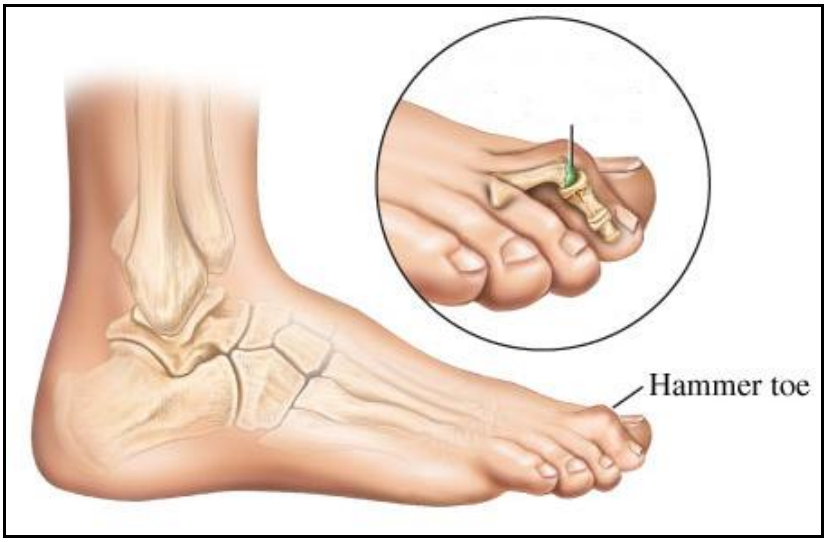

Figure 2.4: Hammer toe osteoarthritis. (Marat, 2012)

The other foot OA that always affects the human foot joints is corns and calluses which are the areas of thickened and dry skin. Normally, corns will develop around the toes and it can be found at top and the bottom of the foot skin. Meanwhile, the calluses which are a hard skin usually found at the bottom of the human foot. The corns and calluses (Figure 2.5) should not become a problem if a good foot maintenances is taken but it can built up and causes pain when it is ignored (Arthritis Care, 2012).

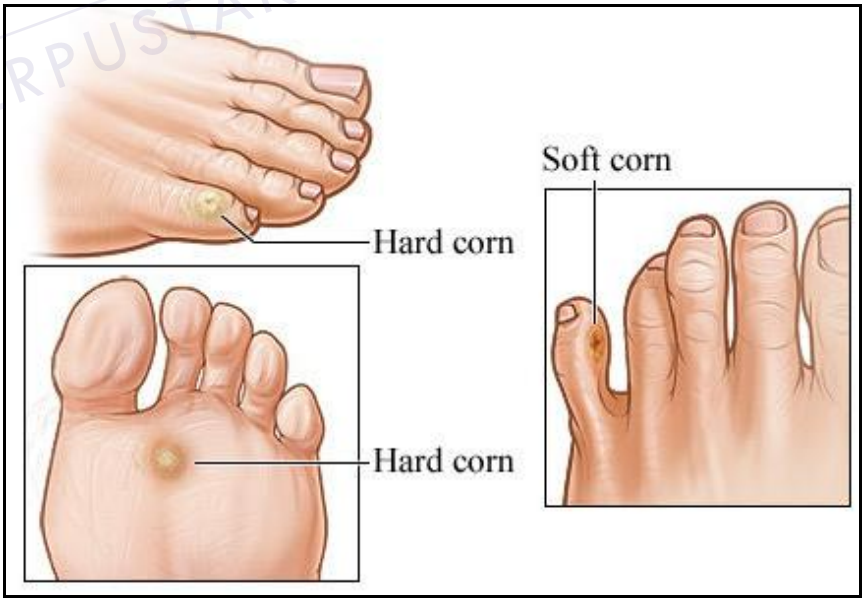

Figure 2.5: Corns and calluses osteoarthritis. (Wisconsin Bone & Joint, 2014)

Foot OA also may be leaded by an old injury and it may take months or years after the injury for the condition to develop. OA in the midfoot is often caused by the sprain or fracture. It also can happen when the midfoot is hit or dropped by something that is hard. In the ankle, OA is usually caused by a fracture and occasionally by a severe sprain. Sometimes OA develop caused of an abnormal human foot mechanics. Usually people who have a flat feet or high arch are risking in developing the foot OA. Less stability in a bands of tissue that is connecting the bone that caused by flat feet will result in excessive strain at the joints. Meanwhile, the high arch which is rigid and lacks mobility will cause a joint jamming that lead to foot OA (Consumer Education Committee, 2006).

2.3.1 Big Toe Osteoarthritis

Big toe is the biggest toe among the toes in human foot. In medical term, the big toe is called hallux. There are three types of big toe OA which are hallux limitus, hallux rigidus and hallux valgus. Normally, the human hallux joint can be move upward at about 90° which is fully upward bending and it will bending about 45° while walking. The hallux limitus shows a reducing of the big toe joint movement that indicate the early of big toe OA. Meanwhile, the hallux rigidus is second stage of big toe OA where the big toe joint will not move normally (NHS Trust, 2013). The comparison between the motion of hallux limitus and rigidus to the normal motion of big toe is shown in Figure 2.6.

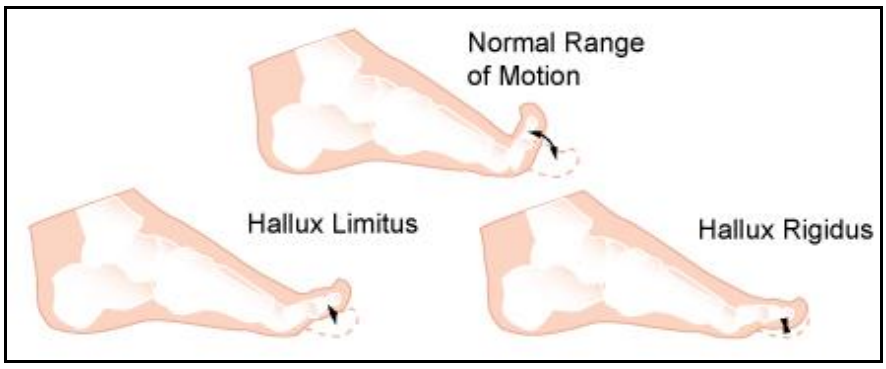

Figure 2.6: The comparison between the motion of hallux limitus and rigidus to the normal motion of big toe. (OurHealthNetwork.com, 2006)

The big toe OA as shows in Figure 2.7 always affect the joint at the big toe and it may push the big toe toward the other toes. This condition will make the damage big toe overlapping the nearest toe and it will feel pain while walking or long time standing. It also can lead to a bunion which is also known as hallux valgus. Hallux valgus usually affects the human with age older than 40 years old (Abhishek *et. al.*, 2010). The patients who having bunion will face the problem in choose a suitable shoes to comfort their foot. It is because the bunion will enlarge the joint at the base and the side of the big toe. When wearing some close shoes, the patient feel pain and difficult to walk due to the pressure that the joints. The imbalance in the forces inside the close shoes that exerted across the joint while will lead to worsen bunion.

Figure 2.7: The big toe osteoarthritis. (ModPod Podiatry, 2014)

2.3.2 Big Toe Osteoarthritis Symptom

Even early on, OA in the big toe can cause tenderness, archness, and joint pain. Patient may also feel archness or pain in other toes or in the arch area of their foot while they were walking. Over the time, they may even develop a burning sensation at their movement joints. This big toe disease may be achy after long periods of sitting, or when you first wake up in the morning. Overgrowth of the big toe bone can make it difficult or even impossible to bend the big toe. This results in a stiff toe, also called hallux rigidus (Pietrangelo, 2014).

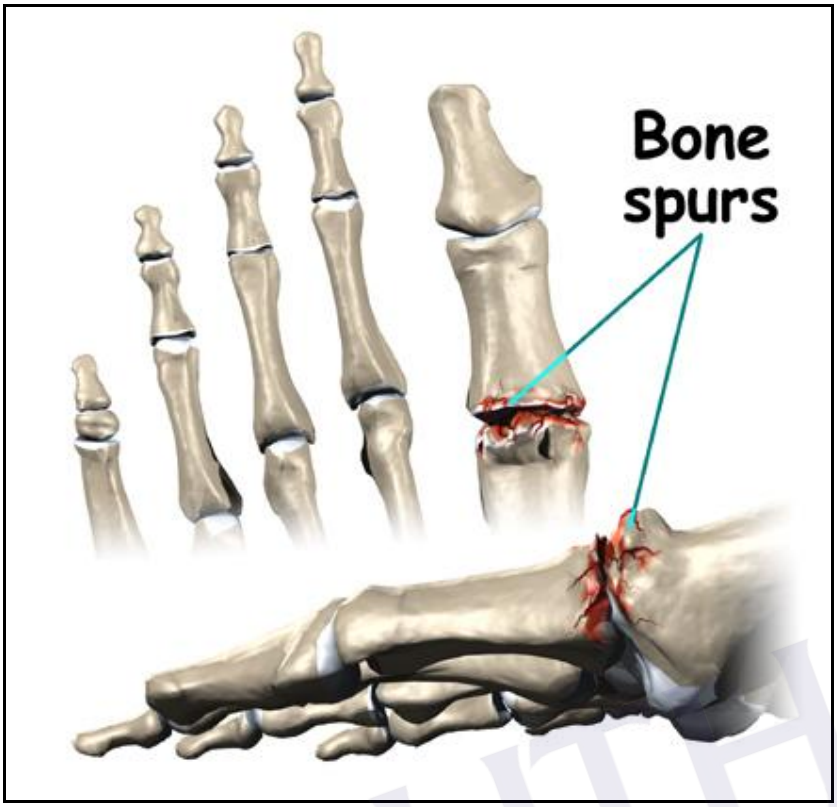

Figure 2.8: The bone spur. (Singh, 2014)

In her health article, Pietrangelo (2014) also said that the big OA symptoms can be know by the appearance changing of the foot. An OA causes inflammation, so it probably can be noticed by patient in feeling some swelling around the joint of their toe. Damaged cartilage causes bones to rub against together. In time, this can cause bony protrusions or also called as bone spurs as shown in Figure 2.8. Usually the patients may be unaware of bone spurs until it develops a visible bump or callus on their toe. As the big toe changes, it can start to push against the other toes, causing the joint at the base of the big toe to become enlarged (bunion).

Another symptom of the big toe OA is the patients will face the problem difficult in walking or doing daily activities. Walking can be a problem if they cannot bend their big toe. The imbalance force in the way the patients walk can make the bunion likely to develop wether the patient already have a bunion or not. As they walk, bunions push against their shoes, causing their big toe to push against the other toes. This makes walking painful and uncomforted. Over the time, these bunions can lead to corns, calluses, and hammer toes (Pietrangelo, 2014).

2.3.3 Big Toe Osteoarthritis Causes

According to Pietrangelo (2014), the risk of big toe OA increases by aging process due mostly to wear and tear. That why it is known as degenerative arthritis which its nature to develop as part of aging process. When human become older, their risk in affected by OA is high. Human bodies become less able to heal damaged cartilage as they grow older. People are more likely to develop OA if they have a family history of it, or if they are obese. It shows that, one of the causes people affected by OA disease is through the genetic. If their family members had effected by this disease, they probably may be affected by some OA.

The big toe OA also affect human because of repetitive minor trauma or injury during their daily or occupational activities (NHS Trust, 2013). These activities may lead to degenerative changes over the times. For the example, we fall down on the ground because of accidentally step some hard object on the ground by our big toe. Repetitive this minor injury will lead to big to OA disease. Hallux rigidus also may be the result of a toe injury or deformity of the foot. Stiffness in the big toe generally begins between the ages of 30 and 60. If people had some major injury, it may take months or years after the injury for the condition to develop.

Another cause of big toe OA is repeated stress and use over the time (NHS Trust, 2013). The joints at the big toe will wear and tear because of this repeated stress due to the repeated activities. For the example, OA in a big toe and hammer toes often caused by kicking or jamming the toe toward some object that is hard. There are some people who have a habit to kicking their toes toward some object wether it soft or hard when their feet are doing nothing. It may not feel pain at early stage but with a repeated force into the toes will develop the OA diseases.

Wearing of shoes that are appropriate with the foot also may lead to big toe OA. If wearing the shoes that are too narrow at the end of toes, the big toe may push its nearest toe to fit with the shoe. The toes in shoes will be overlapping with each other and with repeated of this situation, the toes will be pain and stiff. It is also happened to the females who always wearing a high heel. The pressure of the body

weight will not distribute fairly at the foot. The area forefoot will be getting more pressure than midfoot and rearfoot.

2.4 Osteoarthritis Treatments

Treatment is a therapy method that is use by the medical group to remedy the health problem. OA diseases should be having their own treatment to relieve the pain that had been feel by the OA patients. Whether it is a surgical treatment or non-surgical treatment, the goal of treatment is to reduce joint pain and inflammation while improving and maintaining joint function. As we know, the OA disease is a degenerative arthritis which is develop with aging process. We cannot prevent the foot from affected by the OA disease but we can prevent it from become worse.

Based on Shiel Jr. (2014) work, beside weight reduction and avoiding activities that exert excessive stress on the joint cartilage, there is no specific treatment to halt or prevent the cartilage degeneration or to repair damaged cartilage in OA. There are several treatments can be done to this OA disease such as rest, exercise, diet control with weight reduction, physical therapy and/or occupational therapy, and mechanical support devices, such as knee braces.

The treatment methods of OA disease is depend on how severe its condition. In early condition which is the disease is not too severe, it may need a non-surgical treatment but if the non-surgical treatment is fail to adequately reduce the pain that associated with OA, surgery treatment may be recommended. Surgical and non-surgical treatment will be elaborated in another section.

2.4.1 Surgical Treatment

Surgery is generally reserved for those patients with OA that is particularly severe and unresponsive to the conservative treatments. In severe cases, damaged cartilage is removed surgically and the joint is fixed in a permanent position with the pins as shown in Figure 2.9. Surgical options will depend on the severity of the OA disease

condition. The only goal of surgery is to decrease pain and improve function of the foot if there are no more respond from the non-surgical treatment.

Some of the surgery that always be done is osteotomy which is a bone-removal procedure that can help realign some of the deformity in selected patients, usually those with certain forms of knee disease (Shiel Jr., 2014). This type of surgery may be used to realign bones and other joint structures that have become misaligned because of longstanding arthritis. For the knee, realignment may shift weight bearing to healthier cartilage to relieve arthritis pain. This type of alignment may be recommended for younger and more active patients instead of joint replacement surgery (Kalunian, 2014).

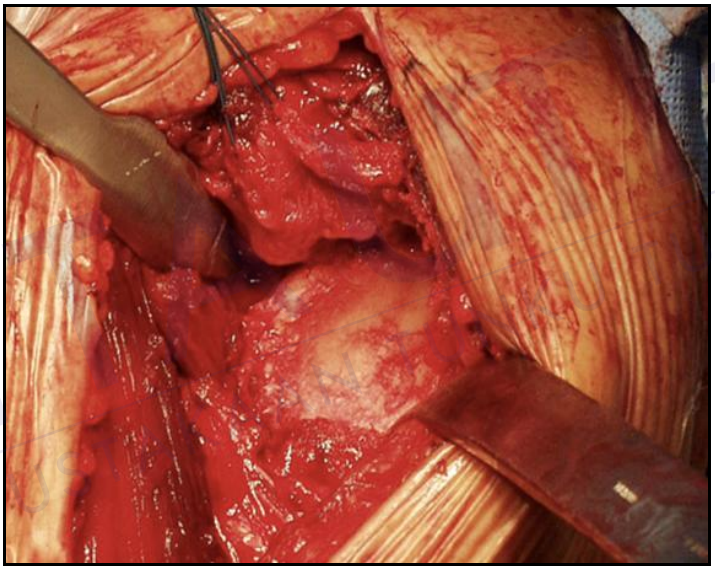

Figure 2.9: Osteoarthritis surgery treatment. (Matsen, 2014)

According to Shiel Jr. (2014), some of the severely degenerated joints are best treated by fusion or also known as arthrodesis in medical term. The surgery may be used to permanently fuse the two or more bones together at a joint. This may be recommended for badly damaged joints for which joint replacement surgery is not appropriate. Fusion may be recommended for joints of the wrist and ankle and for the small joints of fingers and toes (Kalunian, 2014).

An arthroplasty is one of surgery method that is used to cure the OA disease. This arthroplasty is done by the replacement of damaged joint with an artificial joint.

Total hip and total knee replacements are now commonly performed in community hospitals throughout the United States. These can bring dramatic pain relief and improved function (Shiel Jr., 2014). Refer to Kalunian (2014), the most common reason for having joint replacement surgery is pain that is not controlled by a combination of non-pharmacologic and drug treatments. Joint replacement surgery dramatically relieves pain in people with severe arthritis of the hip or knee, and this benefit appears to last for at least three years. However, it may take up to one year before the benefits of joint replacement surgery become fully apparent.

Another surgery method is cartilage grafting that is used to graft new cartilage cells into damaged regions of cartilage. Cartilage grafting is likely to be most practical when the cartilage damage is confined to a very small area that is surrounded by normal cartilage. But this technique is not helpful for patient with large areas of thin or absent cartilage. However, surgery is recommended before arthritis causes complications such as muscle loss and joint deformities. Furthermore, those who undergo surgery should be in the best possible physical condition and should be prepared for rehabilitation after surgery (Kalunian, 2014).

2.4.2 Non-Surgical Treatment

Non-surgical treatment of OA is the most recommended treatment to begin treating the OA to help relieve the symptoms. There are two types of non-surgical treatment which are OA treatment without medication and OA treatment with medication. There are a number of treatments without using the medications. This type of treatment method can substantially improve the arthritis symptoms, and they are usually the first treatments recommended.

According to Kalunian (2014), the arthritis symptoms are typically worsened by activity can be improved with rest of the joint movement. However, a complete lack of activity can lead to a loss of muscle and joint stiffness. If arthritis flares and causes significant pain and inflammation, the healthcare provider may recommending the patient to rest for 12 to 24 hours, followed by a return to usual activities. In fact, modest weight reduction can help to decrease symptoms of OA of

the large joints, such as the knees and hips. This is because obesity is strongly linked to the development of arthritis of the knee. The weight of an obesity patient will produce overpressure in the joint that support the weight human body which is known as weight bearing joint. Losing more weight may reduce the pain in weight bearing joints, such as the hips and knees.

Figure 2.10: Physical therapy and exercise for knee osteoarthritis. (Piazza, 2012)

Kalunian (2014) also mention in his article that a physical therapy and exercise as shown in Figure 2.10 can improve flexibility and strengthen the muscles surrounding the joints. People who exercise regularly despite their arthritis will typically have less pain and better function than those who are inactive. Beside that, the heat and cold therapies also can be applied to arthritic joints can help to control arthritis symptoms such as pain and stiffness. Heat can be applied to the joints with hot packs, hot water bottles, heating pads, or electrically heated mittens. Heating pads should be set on a timer and used for no more than 20 minutes at a time. This is important to avoid burning on the patient skin. Cold can relieves pain in arthritic joints and reduces muscle spasms. It can be applied for short periods using ice packs or coolant sprays.

Figure 2.11: Cold therapy at knee joint. (Osteoarthritis Information, 2010)

According to Arthritis Care (2012), physical treatment such as braces, strapping or insoles can be helpful in reduce pain joint. Braces and strapping can help in limiting the movements in painful joints. While the insoles which is a foot orthoses device as shown in Figure 2.12 is used to take pressure off painful lumps and bumps caused by OA. The orthoses or orthotic devices are a custom device that provides support to keep the joints aligned and functioning correctly. There are many different types of orthoses that can reduce symptoms and that can help maintain function in people with OA (Kalunian, 2014) such as:

- Well-cushioned shoes and orthotic shoe inserts may reduce stress on the joints of the spine and leg.
- Splints (Figure 2.13) is cast boot that immobilize the joints can reduce pain and inflammation, and many splints can be worn throughout the day and night.
- Pad support which is in different types of features and application. but the goal of pad support is to relieve the joint pain and prevent it from become worse. In this research will be design the pad support for treating the big toe osteoarthritis disease.

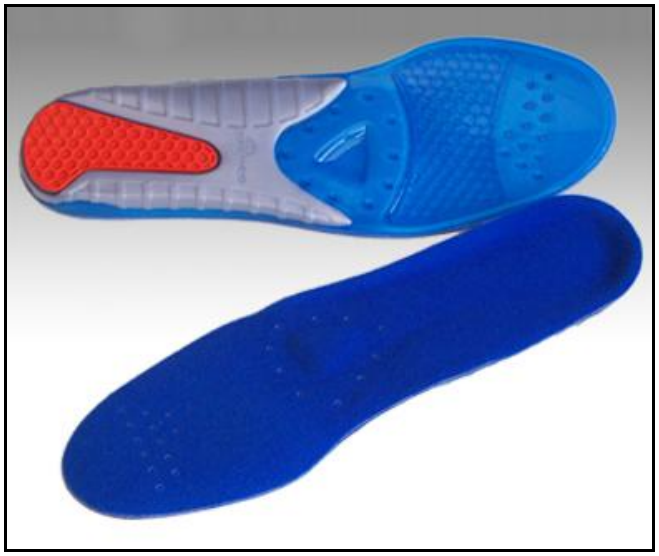

Figure 2.12: Insoles - foot orthotic device. (Feet Relief, 2007)

Figure 2.13: Splint - immobilization treatment.
(OrthopaedicsAndTrauma.com, 2014)

The OA patient also should have some knowledge about their OA disease. This will be easy to the patient in handling their disease to take their step in reduce the symptoms if they have some education in their disease. By learning more about OA, patient can better participate in their own care. It is important to discuss the options for the treatment of arthritis, the effects of arthritis on daily activities, and the strategies for coping with the limitations imposed by arthritis with their healthcare provider. Kalunian (2014) mentioned that some studies suggest that

psychosocial support may be as effective as drug therapy for reducing the symptoms of arthritis. Support can be achieved by building an informal support network or by participating in formal arthritis support group.

Another non-surgical treatment is the osteoarthritis treatment with medication. It also known as drug therapy where it use some medication (Figure 2.14) to relieve the pain of the OA disease. Some of the medicine is Analgesics that can relieve pain but do not have any effect on inflammation. These drugs are often recommended when arthritis pain does not respond to non-pharmacologic measures. Acetaminophen (Tylenol and others) can relieve mild to moderate arthritis pain but it can produce rare side effects of kidney and liver damage. It is important to follow dosing instructions and to avoid drinking excessive amounts of alcohol (Kalunian, 2014).

Figure 2.14: Osteoarthritis medicine - drug therapy. (Jasper, 2014)

Referring to Kalunian (2014), non-steroidal anti-inflammatory drugs (NSAIDs) also a drug that relieve pain and reduce inflammation. These drugs are often recommended before analgesics for people who have osteoarthritis and evidence of inflammation. They are also recommended for some people with non-inflammatory osteoarthritis who do not get adequate pain relief with simple analgesics. Another treatment is joint injections which are glucocorticoid (steroid) injections and hyaluronate injections to relive the pain of OA. Medication may be

used topically, taken orally, or injected into the joints to decrease joint inflammation and pain. When conservative measures fail to control pain and improve joint function, surgery can be considered (Pietrangelo, 2014).

2.5 Big Toe Osteoarthritis Pad Support

There are several types of pad support that is use to reduce the pain of big toe joint due to the OA diseases. Some of the pad support that is already existed in the market is "Toe Separator" as shown in Figure 2.15 which is used to prevent in clubbing of the toes during walking (Indiamart, 2014). This type of pad support will have a problem in wearing a closed shoe. The patient will be uncomfortable when wearing it in the shoes while walking. This kind of pad support is suitable for used in resting time after doing daily activities.

Figure 2.15: Toe Separator. (Royal Chemist, 2014)

Another existing product is elastic metatarsal bandage contains a silicone padding at the base and side of big toe joint. The elastic bandage (Figure 2.16) design allows minimal movement in the shoe and keeps the pad secure under foot and prevent the big toe joint from deformation. This product can be used for the foot problems concerning the ball of the foot such as painful metatarsals and forefoot lesions. This product may be suitable for cushioning the forefoot joint but it is not enough tough to prevent the big toe from overlapping its nearest toe. The material

that is use is too flexible. From the customer review on Walmart (2014), the elastic bandage is not thick enough but it will serve as a lightweight protection to the toes. The customer also rates the product on three stars over the total of five star.

Figure 2.16: Elastic metatarsal bandage. (Walmart, 2014)

There also have the simple treatment like used by the patient which is wrapping their big toe by themself using the elastic bandage as shown in Figure 2.17. It may reduce the big joint pain while walking but it will take time to wrapping the toe before walking and unwrap it back. This kind of pad support may use a lowest cost than others pad support.

Figure 2.17: Simple treatment as a pad support for big toe osteoarthritis. (Walmart, 2014)

"Correct Toes" (Figure 2.18) is one of existing product that is use to help big toe OA patients. This toe-spacing product is designed to be worn in shoes during weight-bearing activity, such as running, walking, hiking, and standing. "Correct Toes" has been shown in the correction and prevention of bunions, tailor's bunions, corns, hammer toes, ingrown toenails, heel pain, plantar fasciosis, neuromas, capsulitis, lower leg pain, and runner's knee. In customer review on Walmart (2014), this product is work very well but it makes the shoes too tight and too bulky when wearing it with shoes. This type of pad support is not comfort to wearing it with shoes due to its size is too large. The patient will feel uncomforted while doing their daily activities or work, and this will influence their quality of work.

Figure 2.18: Correct Toes. (Walmart, 2014)

2.6 Conclusion

In this project, the new pad support had been design to support the big toe joint and relieve the big to joint pain. It was design according to the "Correct Toes" which can be worn in shoes while doing daily activities. Differentiation between the new pad support design and "Correct Toes" is the new pad support was designed in a simple geometry that only to be suite in between big toe and its nearest toe. It will not support all the toes like "Correct Toes" product. Because of supporting all the joint toes, the area of plantar foot will be enlarged and this can give problems to OA

patients in wearing shoes. Therefore, the new pad support will be designed to solve this problem by reducing the area of the plantar foot. This new pad support will be placed only in between the big toe and its nearest toe. It will be supported and prevented the big toe joint from overlapping its nearest toe. The other toes are free from any support. This can make the patient feel comfort when wearing it with shoes.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the working procedure to execute the whole projects. Methodology is a step to determine the directions and guidelines to perform the project. Figure 3.1 shows the flow chart of the project that start from an introduction to the project (project objective, project scope and problem statement); literature review of the osteoarthritis diseases (general osteoarthritis, foot osteoarthritis and current design of pad support) and design the pad support using the ABAQUS software. This project will be continued with simulate the pad support using the ABAQUS software (determine the 3 types of material selection and peak pressure value at big toe); get the simulation data; analyze the simulation data and end with discussion.

REFERENCES

ABAQUS 6.13 (2014). *Abaqus/ CAE User Guide*. ABAQUS 6.13 Documentation.

Abhishek, A., Roddy, E., Zhang, W., Doherty, M. (2010). Are hallux valgus and big toe pain associated with impaired quality of life? A Cross-sectional Study. *Osteoarthritis and Cartilage, 18*, pp. 923-926.

Arthritis Care (2012). *Osteoarthritis of the Foot*. Retrieved on March 13, 2014, from http://www.arthritiscare.org.uk

Berenbaum, F. (2013). Osteoarthritis as an inflammatory disease (osteoarthritis is not osteoarthrosis!). *Osteoarthritis and Cartilage*, *21*, pp. 16-21.

Consumer Education Committee (2012). *Osteoarthritis of Foot and Ankle*. American College of Foot and Ankle Surgeon.

Feet Relief (2007). *Spenco Gel Insole – Active energy from start to finish*. Retrieved on March 22, 2014, from http://www.feetrelief.com

FootWise Pediatry (2005). *Plantar Fasciitis – Heel and Arc Spurs*. Retrieved on March 20, 2014, from http://www.footwise.com.au

Guo, L.Y., Lin, C.F., Yang, C.H., Hou, Y.Y., Lui, H.L., Wu, W.L., Ling, H.T. (2012). Effect on Plantar Pressure Distribution with Wearing Different Base Size of High Heel Shoes During Walking and Slow Run. *Journal of Mechanics in Medicine and Biology, 12*, pp. 1-11.

Ho, I.J., Hou, Y.Y., Yang, C.H., Wu, W.L., Chen, S.K., Guo, L.Y. (2010). Comparison of Plantar Pressure Distribution Between Different Speed and Incline During treadmill Jogging. *Journal of Sport and Science Medicine, 9*, pp. 154-160.

Houston Methodist Orthopedics & Sports Medicine (2014). *A Patient's Guide to Osteoarthritis of the Ankle*. Retrieved on March 20, 2014, from http://www.methodistorthopedics.com

Jasper, M. (2014). *Prescription drug for osteoarthritis in lower back*. Retrieved on December 15, 2014, from http://www.tradicrechil.blog.com

Kalunian, K.C. (2014). *Patient Information: Osteoarthritis Treatment (Beyond the Basics)*. Retrieved on March 13, 2014, from www.uptodate.com

Marat, J.P. (2012). *Hammer Toes*. Retrieved on March 20, 2014, from http://health.tipsdiscover.com

Matsen, F.A. (2014). *Shoulder arthritis: osteoarthritis*. Retrieved on March 22, 2014, from http://www.orthop.washington.edu

ModPod Podiatry (2014). *Bunion Management*. Retrieved on March 20, 2014, from http://www.modpodpodiatry.com.au

Nagal, A. and Rosenbaum, D. (2009). Vacuum Cushioned Removal Cast Walkers Reduce Foot Loading in Patient with Diabetes Mellitus. *Gait & Posture*, *30*, pp. 11-15.

NHS Choices (2014). *Osteoarthritis*. Retrieved on March 20, 2014, from http://www.nhs.uk

NHS Trust (2013). *Osteoarthritis of big toe joint*. Retrieved on March 20, 2014, from http://www.leedcommunityhealthcare.nhs.uk/msk

OrthopaedicsAndTrauma.com (2014). *Foot and Ankle Support*. Retrieved on March 22, 2014, from http://www.orthopaedicsandtrauma.com

Osteoarthritis Information (2010). *Cold Therapy for Knee Osteoarthritis*. Retrieved on March 22, 2014, from http://www.osteoarthritisblog.com

OurHealthNetwork.com (2006). *Hallux Rigidus and Hallux Limitus*. Retrieved on March 20, 2014, from http://www.ourhealthnetwork.com

Piazza, C. (2012). *Physical Therapist Guide to Osteoarthritis of The Knee*. Retrieved on March 22, 2014, from http://www.progressiveptinc.com

Pietrangelo, A. (2014). *Osteoarthritis of the Big Toe: Symptoms, Causes and Treatments*. Retrieved on March 13, 2014, from http://www.healthline.com

Plastic International (2014). *Polypropylene Copolymer*. Retrieved on August 9, 2014, from http://www.plasticsintl.com

Royal Chemist (2014). *Foot Care Product*. Retrieved on April 10, 2014, from http://www.indiamart.com

Shiel Jr., W.C. (2014). *Osteoarthritis*. Retrieved on March 13, 2014, from www.onhealth.com

Singh, A.P. (2014). *Bone Spur or Osteophyte*. Retrieved on March 22, 2014, from http://www.boneandspine.com

Walmart (2014). *Health Foot Care Product*. Retrieved on April 10, 2014, from http://www.walmart.com

WebMD (2013). *Joint Often Affected by Osteoarthritis*. Retrieved on March 20, 2014, from http://www.webmd.com

Wisconsin Bone and Joint (2014). *Corns*. Retrieved on March 20, 2014, from http://www.wiscboneandjoint.com